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F1V
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(54) Rotary non-positive displacement compressor

(57) A compressor comprises an impeller wheel 12 including a plurality of vanes or blades 14 each of which includes a leading edge 16, a trailing edge 18 and an outer free edge 20, said wheel 12 being mounted for rotation within a stationary housing 10, said housing having a gas inlet 24 and a gas outlet arranged such that the vanes or blades 14 are disposed in the gas path between said inlet 24 and said outlet, and a circumferentially extending series of stationary slots 40 formed in a ring 28 disposed at the periphery of the impeller wheel 12, and each extending parallel to the axis of the wheel 12, the leading edges 42 of said slots being open and disposed upstream of a radial plane normal to the axis of rotation of the wheel and through the junctions 21 between the leading edge 16 of each blade or vane 14 and the outer free edge 20 of each blade or vane 14. The arrangement of the present invention is believed to increase the range of r.p.m. over which compressors can operate in stable manner. Alternative embodiments involving both axial and radial flow compressor stages, and including bleed hole arrangements, are also disclosed (Figs. 3 to 7).

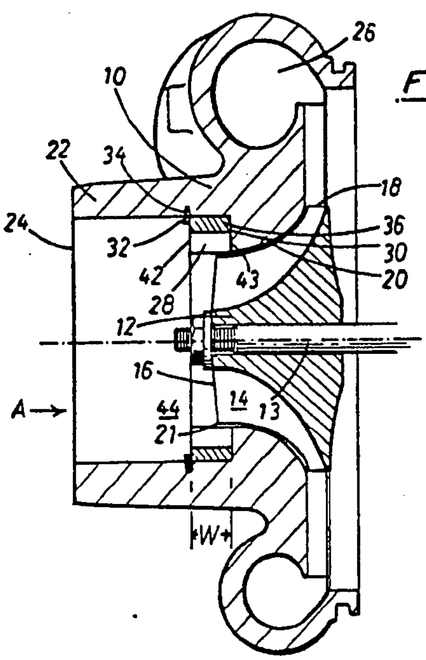

Fig 1

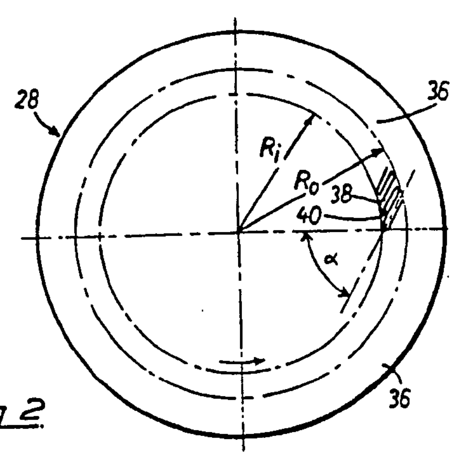

Fig 2

The drawing(s) originally filed was (were) informal and the print here reproduced is taken from a later filed formal copy.

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1982.

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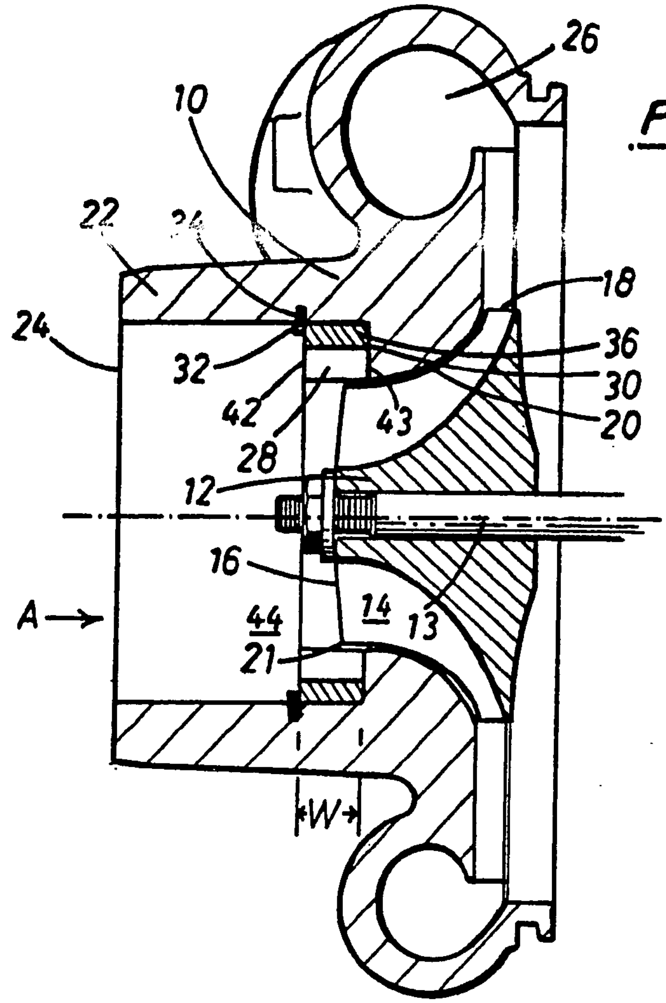
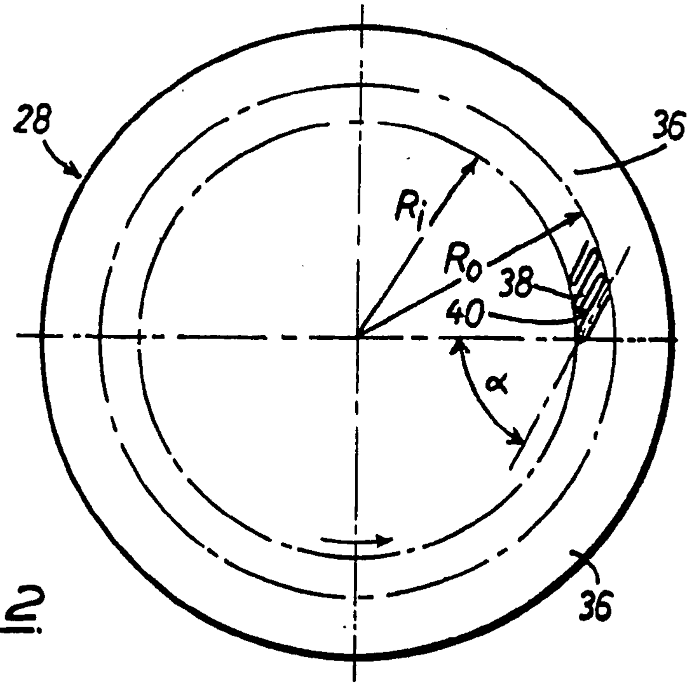


26
10
22
24
18
24
32
36
30
42
43
20
28
12
16
14
13
A
44
21
W

Fig 1



28
36
R_i
R_o
38
40
α
36

Fig 2

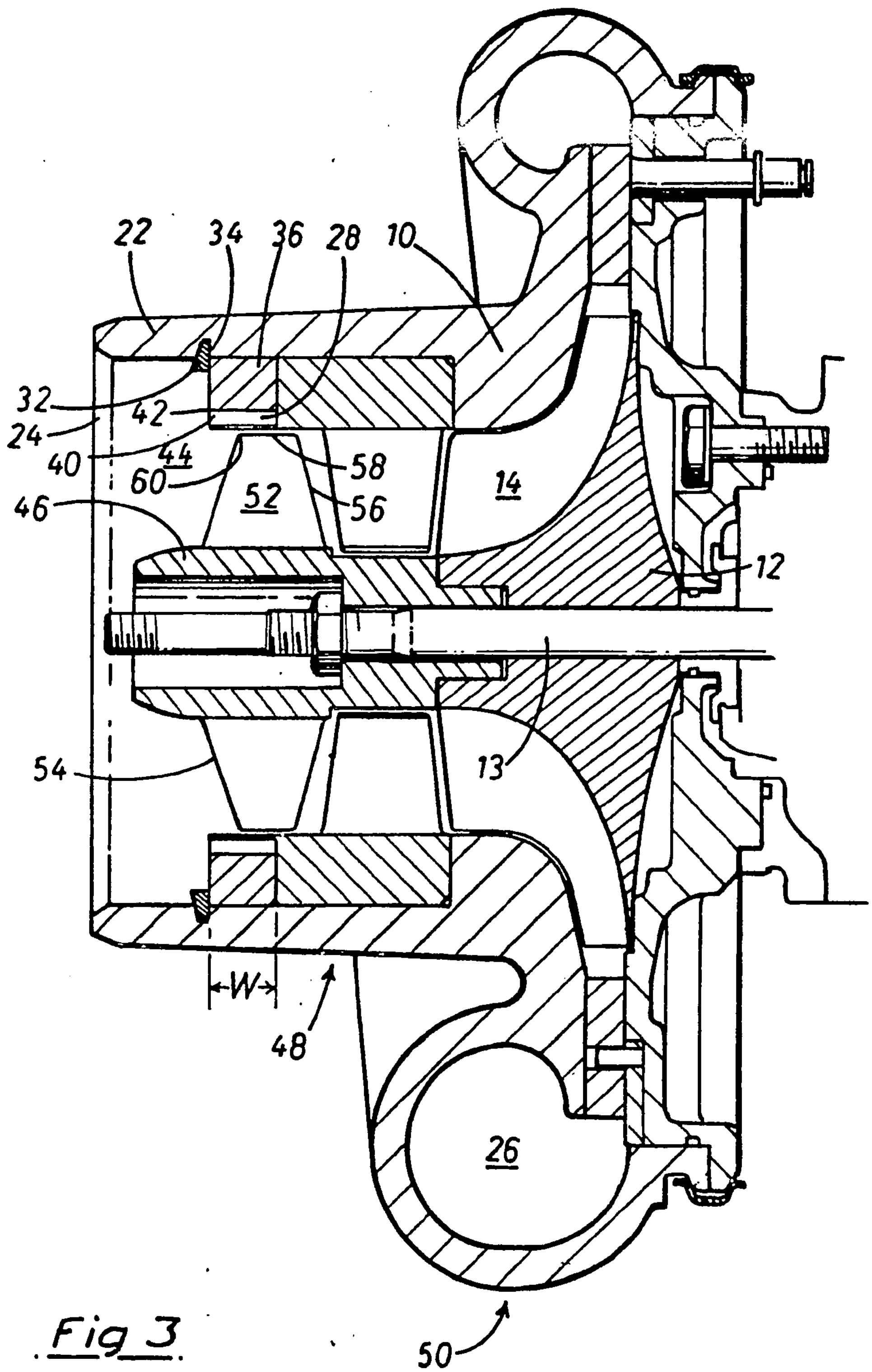


Fig 3.

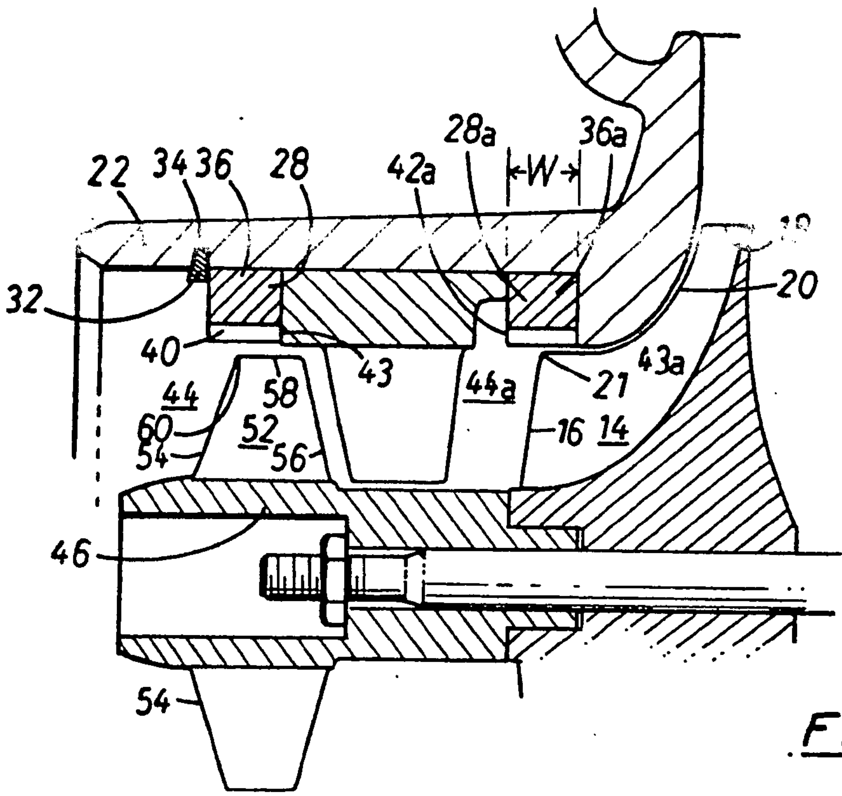

22
34
36
28
42a
28a
W
36a
18
32
20
40
43
43a
21
44
58
44a
60
52
16
14
54
56
46
54

Fig 4

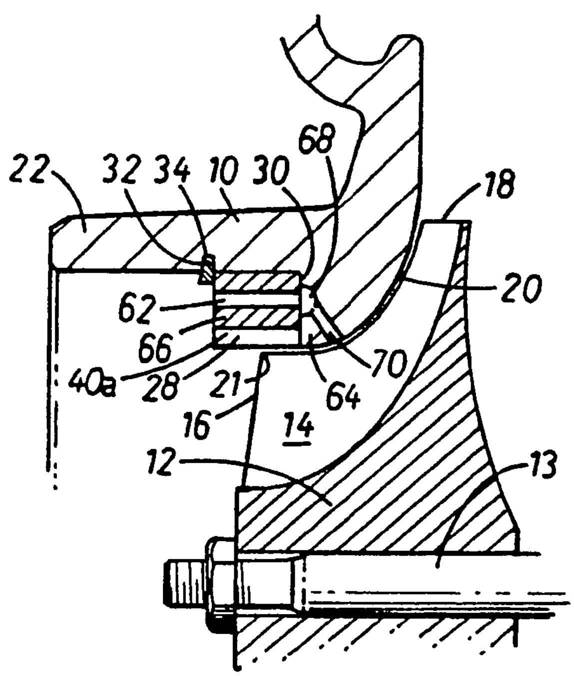

68
22
32
34
10
30
18
62
20
66
70
40a
28
21
64
16
14
12
13

Fig 5

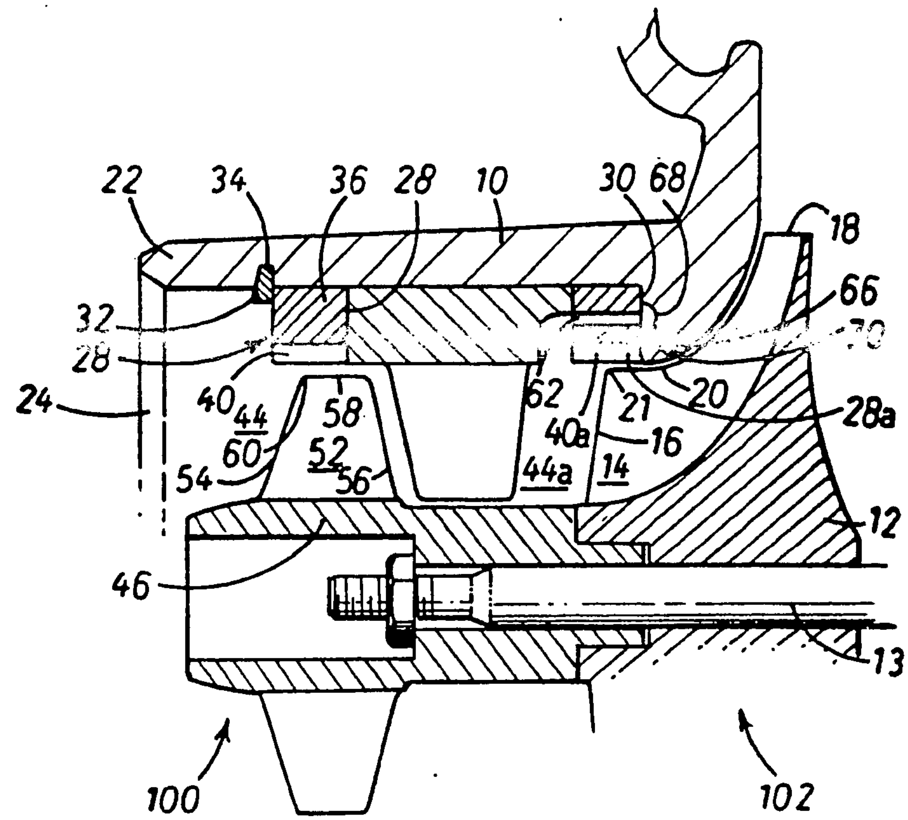

22
34
36
28
10
30
68
18
66
32
70
28
20
24
40
44
58
62
21
28a
40a
16
60
52
44a
14
54
56
12
46
13
100
102

Fig 6

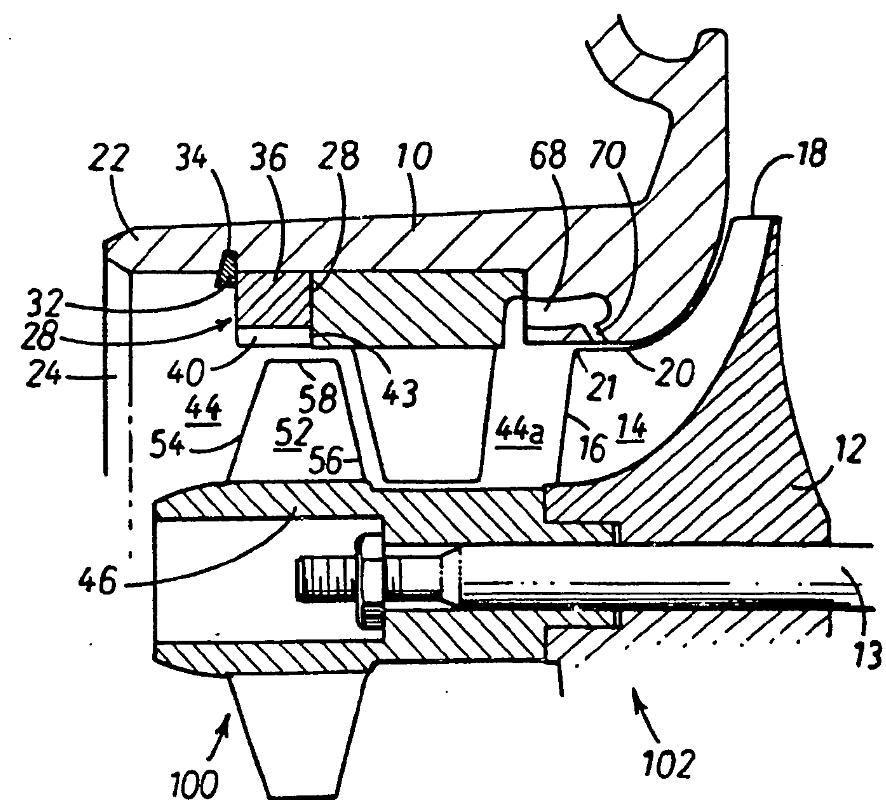

22
34
36
28
10
68
70
18
32
28
24
40
43
21
20
58
44
44a
14
54
52
56
16
12
46
13
100
102

Fig 7

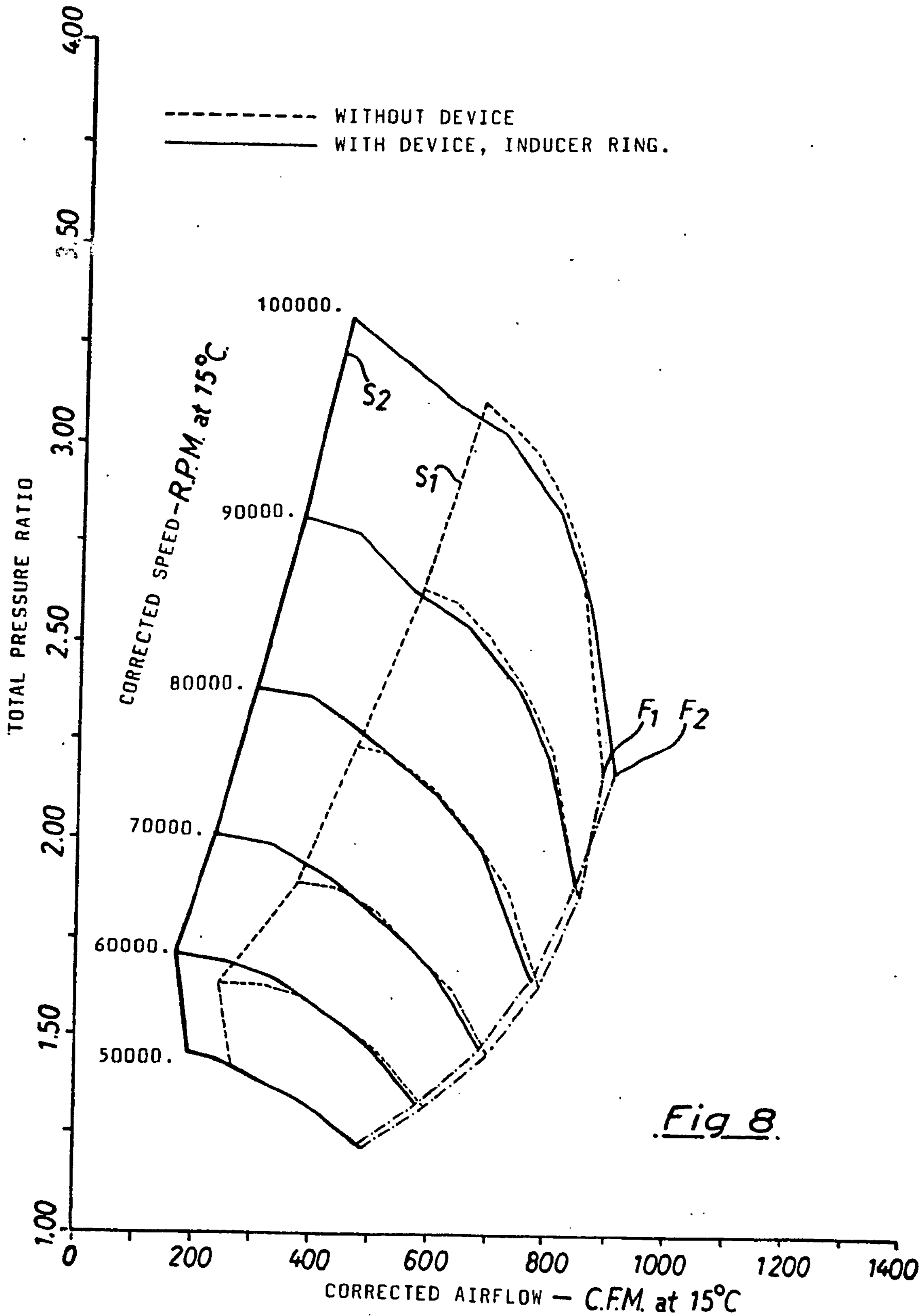
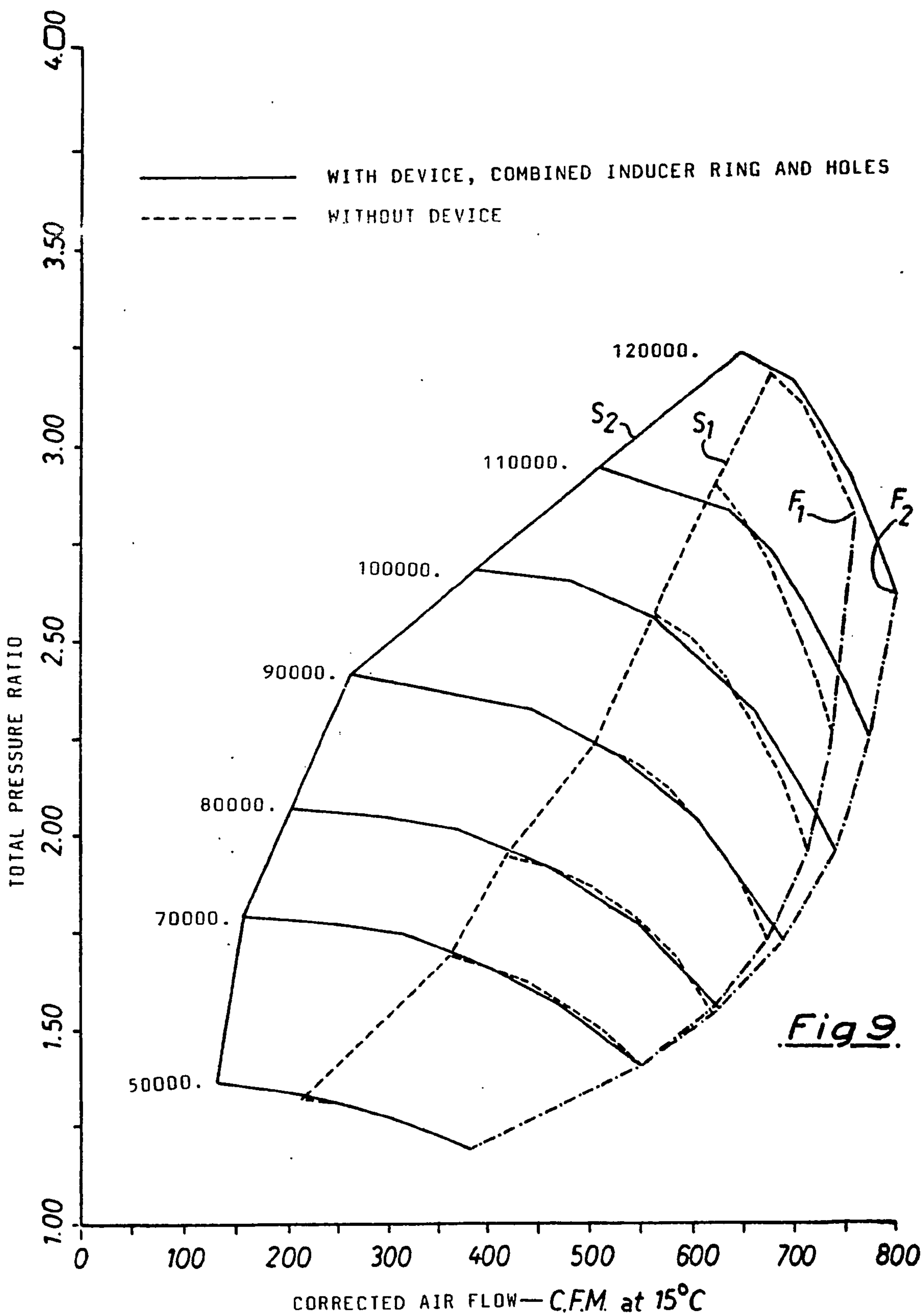

WITHOUT DEVICE
WITH DEVICE, INDUCER RING.
TOTAL PRESSURE RATIO
CORRECTED SPEED-R.P.M. at 15°C
CORRECTED AIRFLOW — C.F.M. at 15°C
100000.
90000.
80000.
70000.
60000.
50000.
S2
S1
F1
F2
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0
200
400
600
800
1000
1200
1400

Fig 8



WITH DEVICE, COMBINED INDUCER RING AND HOLES
WITHOUT DEVICE
TOTAL PRESSURE RATIO
4.00
3.50
3.00
2.50
2.00
1.50
1.00
120000.
110000.
100000.
90000.
80000.
70000.
50000.
S_2
S_1
F_1
F_2
0
100
200
300
400
500
600
700
800
CORRECTED AIR FLOW— C.F.M. at 15°C

Fig 9.

"IMPROVEMENTS IN AND RELATING TO COMPRESSORS"

The present invention relates to compressors e.g. axial and centrifugal compressors and multi-stage versions thereof.

Compressors normally comprise an impeller wheel, carrying a plurality of blades or vanes, and mounted on an axis for rotation within a stationary housing. Rotation of this impeller wheel causes gas (usually air) to be drawn into the impeller wheel and to be discharged to a passage or passages for transferring the compressed gas to its destination. In the case of a centrifugal compressor the gas is discharged radially and in the case of an axial compressor the gas is discharged axially. In the case of a turbine driven compressor in e.g. a turbocharger, the compressor impeller wheel and the turbine wheel are mounted on a common axis so that rotation of the turbine wheel causes rotation of the impeller wheel.

It has been proposed in U.S. Specification No. 4,212,585 to provide a stationary slotted ring comprising a circumferentially extending series of slots adjacent the leading edges of a series of compressor vanes such that there is relative motion between this series of slots and the vanes as the impeller rotates.

In this arrangement however the whole, or virtually the whole, of the axial length of the slots (i.e. from leading edge to trailing edge) overlaps the

impeller wheel and the leading edges of the slots are enclosed. Such an arrangement, when incorporated in the compressor of a turbocharger, provides stable operation over a wider range of engine r.p.m. than a similar compressor without the slotted ring, but there is now a requirement to increase even further the engine r.p.m. range over which compressors can operate in stable manner. This is achieved in accordance with the present invention by providing a slotted ring comprising a circumferentially extending series of slots adjacent the leading edge of a compressor impeller, the leading edges of the slots being some way upstream of the impeller wheel and the leading edges of the slots being open.

According to the present invention therefore there is provided a compressor comprising an impeller wheel including a plurality of vanes or blades each of which includes a leading edge, a trailing edge and an outer free edge, said wheel being mounted for rotation within a stationary housing, said housing having a gas inlet and a gas outlet arranged such that the vanes or blades are disposed in the gas path between said inlet and said outlet, and a circumferentially extending series of stationary slots disposed at the periphery of the impeller wheel,and each extending parallel to the axis of the wheel, the leading edges of said slots being open and disposed upstream of a radial plane normal to

the axis of rotation of the wheel and through the junctions between the leading edge of each blade or vane and the outer free edge of each blade or vane.

The slots may be formed in the housing itself or, more preferably, may be in a separate ring disposed within the housing.

Preferably the distance from the leading edge of the slots to said radial plane is at least 50% (and more preferably 50 to 60%) of the axial length of the slots. Opposing faces of each slot are preferably parallel so that the slots are of constant width substantially throughout, and in this event, the tongue between each pair of adjacent slots needs to be tapered accordingly. Each slot is preferably at an angle of 60° to a radial line at intersection between said radial line and a circle touching the ends of the tongues between the slots.

The slots are preferably such that the ratio of the outer diameter of the slots to the inner diameter of the slots is from 1.12 to 1.17.

Preferably the axial length of the slots is 17 to 21% of the inner diameter of the slots.

In a further embodiment the compressor also includes a bleed arrangement as described in co-pending Applications Nos. 8531739 and 8600884.

According to a further embodiment of the present invention therefore the stationary housing includes an inner wall and an outer wall, at least part of the inner wall being in close proximity to, and of similar contour to, the outer free edges of the blades or vanes, and forming an inlet to the impeller wheel in a region adjacent the leading edges of said blades or vanes, said outer wall forming a gas intake surrounding said inner wall and extending in an axial direction, a chamber preferably an annular chamber, is formed between said inner and outer walls in a region, preferably at least partly surrounding said blades or vanes, and communication being provided through said inner wall between said chamber and the inner surface of said inner wall whereby gas may pass between the area swept by the vanes or blades and the chamber. The inner wall may be partly formed by a portion of the slotted ring.

The communication between the chamber and the inner surface of the inner wall may be an annular slot extending around the inner wall and bridged by a series of connecting webs or may be a plurality of holes.

In the event that the communication comprises a plurality of holes then it is preferred that the number of such holes is not equal to, or a multiple of, or a factor of, the number of blades or vanes on the impeller wheel. Excitation may well occur in the event that the number of such holes is equal to, a

multiple of, or a factor of, the number of blades or vanes. The preferred number of holes (subject to the above condition) is from 29 to 43.

Preferably the total area of the holes or the slot at the inner surface of the inner wall is from 13 to 23% of the inducer annular area (i.e. the frontal area of the impeller wheel at the leading edge minus the hub area).

In the case of a centrifugal compressor of the invention also including said bleed arrangement, preferably the bleed holes or slots are located at a point some 22 to 34% from the leading edges of blades or vanes along the meridional length. Preferably the slots of the slotted ring overlap the blades by an amount which is some 15 to 20% of the meridional length from the leading edges of the blades and some 30 to 50% of the axial length of the slots.

In the case of an axial compressor preferably the holes or slots are located at a point 15 to 25% of the distance from the leading edge to the trailing edge of the blades or vanes and the slots overlap the blades by some 5 to 14% of said distance.

During operation of the compressor of the invention gas may pass through the slots. During high flow and high r.p.m. operation air may flow into the impeller wheel via the open-ended slots thereby increasing the flow capacity of the compressor. During operation near the surge line, the slots provide communication between

each side of an impeller blade or vane and tend to reduce the pressure differential existing between the two sides of each blade or vane, thereby tending to stabilise airflow through the compressor. Pressure differentials existing along the length of each slot from its leading edge to its trailing edge are similarly reduced tending to further stabilise airflow.

In embodiments which also include the bleed arrangement, high flow and high r.p.m. operation causes the pressure at the impeller end of the bleed slot or holes to be less than the pressure at the chamber end of the bleed slot or holes and air thus flows through the slot or holes from the annular chamber to the impeller wheel thereby increasing the amount of air reaching the impeller wheel. During operation of the compressor near its surge line however, the pressure at the impeller end of the bleed slot or holes increases to above that at the chamber end of the bleed slot or holes and thus air bleeds out of the area swept by the impeller wheel, through the bleed slot or holes and through the annular chamber, thereby reducing the amount of air in the impeller wheel. The air bleeding out of the impeller wheel is thus recirculated to the inlet. This stabilises compressor operation, moving the surge line to lower flow over the entire r.p.m. range of the compressor.

Use of the compressor of the present invention, either with or without the bleed arrangement, enables

compressor operation over a wider range of engine r.p.m. than was previously possible.

The compressor of the present invention is especially useful when forming part of a turbocharger for an internal combustion engine particularly where an air cleaner is provided upstream of the air intake to the compressor.

This latter preference is especially so when the bleed arrangement is present because the air cleaner results in the air pressure in the intake being depressed below atmospheric to a greater extent than without an air cleaner and thus results in even better operation of the compressor of the invention due to the pressure differential between the two ends of the bleed slot or holes at low flow (i.e. near surge) being greater.

In a multi-stage compressor a number of compressors e.g. axial, centrifugal or both are connected in series so that the outlet from one compressor leads to the inlet of the next compressor in series. One or more of the compressors in such a multi-stage arrangement may be in accordance with one or more embodiments of the invention and, if desired, one or more compressors may be in accordance with the invention as described in Specifications Nos. 8531739 and 8600884.

The invention will now be further described, by way of example, with reference to the accompanying

drawings, in which :-

Figure 1 is a part cross-section through part of a compressor in accordance with one embodiment of the present invention ;

Figure 2 is a view of the direction of arrow A in Fig. 1, of one component of the compressor ;

Figure 3 is a view partly in cross-section of a compressor in accordance with a second embodiment of the present invention ;

Figure 4 is a view partly in cross-section of part of a compressor in accordance with a third embodiment of the present invention ;

Figure 5 is a view partly in cross-section of part of a compressor in accordance with a fourth embodiment of the present invention ;

Figure 6 is a view partly in cross-section of part of a multi-stage compressor in accordance with the present invention ;

Figure 7 is a view partly in cross-section of part of another multi-stage compressor in accordance with the present invention ;

Figure 8 is a graph plotting airflow against pressure comparing a compressor in accordance with one embodiment of the invention with a compressor which is not in accordance with the invention ; and

Figure 9 is a graph plotting airflow against pressure comparing a compressor in accordance with another embodiment of the invention with a compressor which is not

in accordance with the invention.

Where appropriate like numerals are used throughout the drawings to indicate like parts.

Referring now to Figures 1 and 2, there is shown a partly cross-section view of a single stage centrifugal compressor comprising a housing 10 having an impeller wheel 12 mounted in conventional manner on a shaft 13 for rotation in the housing 10.

The wheel includes a plurality of blades or vanes 14 of conventional design and each including a leading edge 16, a trailing edge 18 and an outer free edge 20. On each blade or vane, leading edge 16 meets outer free edge 20 at a corner 21. The housing includes a wall 22, defining an intake 24 for gas such as air, and a passageway or passageways 26 for carrying compressed gas from the impeller wheel 12 to its destination e.g. the inlet manifold of an internal combustion engine.

A slotted ring 28 (see also Figure 2) made of aluminium, plastic or other suitable material, is located adjacent the periphery of the wheel 12 and is held in position adjacent a shoulder 30 formed in the housing by a tapered circlip 32 which partially fits into groove 34 formed in the inner surface of the wall 22 of the housing 10. As can be seen in Figure 2 the slotted ring comprises a solid portion 36 having a series of sixty equally spaced projections 38 thereby forming sixty equally spaced slots 40 therebetween. The slots 40 are of

constant width (1 mm) (i.e. distance between two adjacent projections 38) and the projections thus taper slightly to allow for this. Each projection is arranged such that a radius to the free end of the projection is at an angle of 60° to the projection (see angle α on Fig. 2). The ratio of the slot outer radius (Ro) to the slot inner radius (Ri) is from 1.12 to 1.17 and the axial length (W) is from 17 to 21% of the inner radius (Ri).

The slotted ring 28 overlaps the impeller blades or vanes by an amount which is no more than 50% of the axial length W of the slots, i.e. the distance from the leading edge 42 of the ring 28 to radial plane through corners 21 of the blades or vanes is at least 50% of the axial length W of the slotted ring 28. As can be seen in Fig. 1, the leading edge of the slots is open.

In operation the impeller wheel 12 is rotated, e.g. by a turbine wheel (not shown) attached to the shaft 13, and this causes air to be drawn into the impeller wheel 12 through intake 24. The air is compressed by the impeller wheel 12 and is then fed to its ultimate destination via passageway or passageways 26. Because of the blade or vane inlet angle, one or more slots 40 will always axially span each impeller blade or vane 14 providing a path for the communication of pressures between the two sides of each blade or vane to reduce the pressure differential existing therebetween. It is believed this tends to stabilise the airflow through the

compressor and has the effect of moving the surge line from S_1 to S_2 as shown in Figs. 8 and 9. Because the slots 40 are open at their leading edge 42 it is believed they allow communication between pressures existing in the region of the leading edge 16 of the blades or vanes 14 along the length W of each slot 40 between its leading edge 42 and trailing edge 43 further stabilising airflow through the compressor and improving its surge limit. Furthermore during high flow and high r.p.m. operation the pressure in the area swept by the impeller wheel 12 is less than in the intake 24 and thus in the area 44 adjacent the leading edges of the slots. Thus air flows through the slots 40 from the area 44 to the impeller wheel 12 thereby increasing the amount of air reaching the impeller wheel, and increasing its maximum flow capacity from F_1 to F_2 as shown in Figs. 8 and 9. As the flow through the impeller wheel 12 drops or as the r.p.m. of the impeller wheel 12 drops so the amount of air drawn into the wheel 12 through the slots 40 decreases until equilibrium is reached. This particular arrangement results in improved stability of the compressor at all speeds and a shift in the characteristics of the compressor. For example, the surge line is moved as shown in Figs. 8 and 9 from S_1 to S_2 and the maximum flow capacity from F_1 to F_2. The compressor can thus be matched to engines with a wider speed range than can conventional compressors.

Referring now to Figure 3 there is shown a second embodiment of the invention wherein the compressor is a two-stage compressor, the first stage comprising an axial compressor in accordance with the invention i.e. incorporating a slotted ring, and the second stage being a conventional centrifugal compressor. Impeller wheel 46 of an axial compressor 48 and impeller wheel 12 of a centrifugal compressor 50 are each mounted for rotation on a common shaft 13 within a common housing 10. Centrifugal compressor 50 is a conventional compressor in which air is drawn in by the rotation of the impeller wheel 12 (which has blades or vanes 14), is compressed and displaced via passageway 26.

Axial compressor 48 however includes a slotted ring 28 similar to that described in connection with Figs. 1 and 2 and located adjacent the periphery of the impeller wheel 46. The impeller wheel includes a series of blades or vanes 52 each including a leading edge 54, a trailing edge 56 and an outer free edge 58 and on each blade or vane the leading edge 54 and the trailing edge 56 meet at a corner 60. The slotted ring 28 is positioned so that the slots 40 overlap only partially the outer free edge 58 of the impeller wheel 46. The amount of overlap is no more than 50% of the axial length W of the slots (i.e. the distance from the leading edge 42 of the ring 28 to a radial plane passing through corners 60 of the blades or vanes 52 is at least 50%

of the axial length W of the slots). As in the embodiment shown in Figs. 1 and 2 the leading edges of the slots are open.

Operation of the arrangement of Fig. 3 is similar to that of the arrangement of Figs. 1 and 2 except that the air compressed in the compressor 48 is discharged axially and is then subjected to a further compression in the second stage compressor 50.

Improved stability of the compressor at all speeds and an advantageous shift in the surge line is achieved over a similar arrangement without the slotted ring arrangement described.

Clearly if desired the second stage compressor of this arrangement could be omitted and the output from the first stage compressor 48 of this arrangement utilised without a second stage compressor.

Referring now to Figure 4 there is shown an arrangement which is a modification of the arrangement of Fig. 3 in that a slotted ring 28a is provided partially overlapping the impeller 12 of the second stage compressor 50. The slotted ring 28a is similar to that described in connection with Figs. 1 and 2 (the numerals used for various parts of the ring are the same as in Figs. 1 and 2 but with the suffix a) and the overlap is such that the distance between the leading edge 42a of the slotted ring 28a and a radial plane passing through the corners 21 of the blades or vanes 12 is at least

50% of the width W of the slotted ring 28a.

Operation of this arrangement is similar to operation of the arrangement of Fig. 3 but a further improvement in stability and surge characteristics is achieved.

Figure 5 shows a modification of the arrangement of Figs. 1 and 2 wherein in addition to the slotted ring arrangement, an arrangement similar to that described in co-pending Applications Nos. 8531739 and 8600884 is also incorporated. As can be seen from the drawings, the compressor is a single stage centrifugal compressor and as in the arrangement shown in Fig. 1 an impeller wheel 12 is mounted within a housing 10 in conventional manner on a shaft 13 for rotation therewith. As in Fig. 1 the impeller wheel includes a plurality of blades or vanes 14 of conventional design each including a leading edge 16, a trailing edge 18 and an outer free edge 20. Also as in the arrangement shown in Fig. 1 a slotted ring 28 made of aluminium, plastic or other suitable material, is located adjacent the periphery of the wheel 12 and is held in position adjacent a shoulder 30 formed in the housing by a tapered circlip 32 which fits into a groove 34 formed in the inner surface of outer wall 22 of the housing 10. The slotted ring is similar to that described in connection with Figs. 1 and 2 with the exception that a series of holes 62 is formed in the ring. The housing 10 also includes an

inner wall 64 which inner wall continues as, and is partly formed by, the portion 66 of the annular ring 28. Formed between the inner wall 64,66 and the outer wall 22 of the housing is an annular chamber 68 and this annular chamber is connected to the area swept by the impeller wheel 12 by an annular slot (interrupted by a series of connecting webs [not shown]) or a series of holes 70. The portion of the housing adjacent the outer free edge of the impeller wheel is of a contour very similar to that of the outer free edge of the impeller wheel. The holes or slot 70 enter the area swept by the impeller wheel 12 at a position some 22 to 34% from the leading edges of the blades or vanes, along the meridional length of the blades or vanes. The slotted ring overlaps the blades or vanes by an amount which is some 15 to 20% of the meridional length of the blades or vanes and some 30 to 50% of the axial length of the slots. In operation of the compressor the open-ended slots 40 act as described in connection with Figs. 1 and 2. The bleed arrangement comprising chamber 68, slot or holes 70 and holes 62 operates as described in co-pending Applications Nos. 8531739 and 8600884, such that during high flow and high r.p.m. operation air flows to the impeller wheel via holes 62, chamber 68 and a slot or holes 70, thereby increasing the amount of air reaching the impeller wheel and during operation near the surge line of the compressor air bleeds out of the area swept by the impeller wheel via the reverse path, thereby reducing the amount of air

in the impeller wheel. Air bled out in this way is recirculated.

An additional advantage is obtained from such a combined arrangement in that the surge line is moved even further. As can be seen in Fig. 9 the surge line is moved from S_1 to S_2 by utilising a device as shown in Fig. 5 and the compressor can thus be matched to engines with a much wider speed range than can conventional compressors.

Referring now to Figure 6 there is shown a multi-stage compressor comprising an axial compressor 100 and a centrifugal compressor 102. This multi-stage compressor is very similar to that shown in Fig. 4 with the exception that the centrifugal compressor 102 is the same as that shown in Fig. 5 and thus includes in addition to the slotted ring arrangement, the bleed arrangement. Operation of the device is as described in connection with Figs. 4 and 5 with the obvious exception that additional benefit is gained from the bleed arrangement.

Referring now to Figure 7 there is shown a multi-stage compressor comprising an axial compressor 100 similar to that described in connection with Figs. 4 and 6 and including the slotted ring arrangement of the present invention and a second stage centrifugal compressor 102 including the bleed arrangement of co-pending Applications Nos. 8531739 and 8600884 but not including the slotted ring arrangement. The first stage of this arrangement

operates in similar manner to the first stage of each of the arrangements of Figs. 4 and 6. The second stage of this arrangement operates in a similar manner to the second and third stages of the arrangement of Fig. 6 of Applications Nos. 8531739 and 8600884.

It will be appreciated that many modifications of the arrangements shown in the drawings may be effected within the scope of the present invention especially where the multi-stage compressors are used. For example additional compressor stages may be added and the various compressor stages may be varied from those shown in the drawings. For example, a centrifugal compressor (first stage) including a slotted ring but no air bleed arrangement may be combined with a centrifugal compressor (second stage) including both slotted ring and air bleed arrangement.

Figures 8 and 9 have been referred to previously in connection with the arrangement shown in certain earlier figures and are graphs plotting total pressure against corrected airflow.

CLAIMS

1. A compressor comprising an impeller wheel including a plurality of vanes or blades each of which includes a leading edge, a trailing edge and an outer free edge, said wheel being mounted for rotation within a stationary housing, said housing having a gas inlet and a gas outlet arranged such that the vanes or blades are disposed in the gas path between said inlet and said outlet, and a circumferentially extending series of stationary slots disposed at the periphery of the impeller wheel, and each extending parallel to the axis of the wheel, the leading edges of said slots being open and disposed upstream of a radial plane normal to the axis of rotation of the wheel and through the junctions between the leading edge of each blade or vane and the outer free edge of each blade or vane.

2. A compressor as claimed in claim 1, in which the slots are formed in a separate ring disposed within the housing.

3. A compressor as claimed in claim 1 or 2, in which the distance from the leading edge of the slots to said radial plane is at least 50% of the axial length of the slots.

4. A compressor as claimed in claim 3, in which the distance from the leading edge of the slots to

said radial plane is from 50 to 60% of the axial length of the slots.

5. A compressor as claimed in any one of the preceding claims, in which opposing faces of each slot are parallel so that the slots are of constant width substantially throughout, and the tongue between each pair of adjacent slots is tapered accordingly.

6. A compressor as claimed in any one of the preceding claims, in which each slot is at an angle of 60° to a radial line at intersection between said radial line and a circle touching the ends of the tongues between the slots.

7. A compressor as claimed in any one of the preceding claims, in which the slots are such that the ratio of the outer diameter of the slots to the inner diameter of the slots is from 1.12 to 1.17.

8. A compressor as claimed in any one of the preceding claims, in which the axial length of the slots is 17 to 21% of the inner diameter of the slots.

9. A compressor as claimed in any one of the preceding claims, in which the stationary housing includes an inner wall and an outer wall, at least part of the inner wall being in close proximity to, and of similar contour to, the outer free edges of the blades or vanes, and forming an inlet to the impeller wheel in a region adjacent the leading edges of said

blades or vanes, said outer wall forming a gas intake surrounding said inner wall and extending in an axial direction, a chamber is formed between said inner and outer walls and communication is provided through said inner wall between said chamber and the inner surface of said inner wall whereby gas may pass between the area swept by the vanes or blades and the chamber.

10. A compressor as claimed in claim 9, in which the inner wall is partly formed by a portion of the slotted ring.

11. A compressor as claimed in claim 9 or 10, in which said chamber is an annular chamber.

12. A compressor as claimed in any one of claims 9 to 11, in which said chamber is in a region at least partly surrounding said blades or vanes.

13. A compressor as claimed in any one of claims 9 to 12, in which the communication between the chamber and the inner surface of the inner wall is an annular slot extending around the inner wall and bridged by a series of connecting webs or is a plurality of holes.

14. A compressor as claimed in claim 13, in which the communication comprises a plurality of holes, the number of which is not equal to, or a multiple of, or a factor of, the number of blades or vanes on the impeller wheel.

15. A compressor as claimed in claim 14, in which the number of holes is from 29 to 43.

16. A compressor as claimed in any one of claims 9 to 15, in which the total area of the holes or the slot at the inner surface of the inner wall is from 13 to 23% of the inducer annular area (i.e. the frontal area of the impeller wheel at the leading edge minus the hub area).

17. A compressor as claimed in any one of claims 9 to 16, which is a centrifugal compressor.

18. A compressor as claimed in claim 17, in which the holes or slots are located at a point some 22 to 34% from the leading edges of blades or vanes along the meridional length.

19. A compressor as claimed in claim 17 or 18, in which the slots of the slotted ring overlap the blades by an amount which is some 15 to 20% of the meridional length from the leading edges of the blades and some 30 to 50% of the axial length of the slots.

20. A compressor as claimed in any one of claims 9 to 16, which is an axial compressor.

21. A compressor as claimed in claim 19, in which the holes or slots are located at a point 15 to 25% of the distance from the leading edge to the trailing edge of the blades or vanes and the slots overlap the blades by some 5 to 14% of said distance.

22. A compressor substantially as hereinbefore described with reference to and as illustrated in any one of Figures 1 to 7 of the accompanying drawings.

23. A multi-stage compressor comprising a number of compressors connected in series so that the outlet from one compressor leads to the inlet of the next compressor in series, one or more of such compressors being a compressor as claimed in any one of the preceding claims.

24. A multistage compressor substantially as hereinbefore described with reference to and as illustrated in any one of Figures 3 to 7 of the accompanying drawings.

25. A turbocharger for an internal combustion engine in which the compressor is in accordance with any one of claims 1 to 24.

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